CHEMISTRY

Goals

The chemistry course encourages students to continue their investigation of the structure of matter along with chemical reactions and the conservation of energy in these reactions. Inquiry is applied to the study of the transformation, composition, structure, and properties of substances. The course focuses on basic chemical concepts and incorporates activities that promote investigations to reinforce the concepts. The curriculum includes inquiry into the following content areas:

- Structure of atoms.
- Structure and properties of matter.
- Chemical reactions.
- Conservation of energy and matter.
- Interaction of energy and matter.

The following explanation introduces teachers to the unifying concepts and program strands. During instruction these concepts should be woven through the content goals and objectives of the course. Supplemental materials providing a more detailed explanation of the goals, objectives, and strands, with specific recommendations for classroom and/or laboratory implementation are available through the Department of Public Instruction's Publications Section.

Unifying Concepts

Unifying Concepts should unite the study of various chemical topics across grade levels.

- Systems, Order and Organization.
- Evidence, Models, and Explanation.
- Constancy, Change, and Measurement.
- Evolution and Equilibrium.
- Form and Function.

Focus on the unifying concepts of science will also help students to understand the constant nature of science across disciplines and time even as scientific knowledge, understanding and procedures change.

Nature of Science

This strand includes the following sections: Science as a Human Endeavor, Historical Perspectives, and the Nature of Scientific Knowledge. These sections are designed to help students understand the human dimensions of science, the nature of scientific thought, and the role of science in society. Chemistry is rich in examples of science as a

human endeavor, historical perspectives on the development of scientific knowledge, and the nature and role of scientific knowledge.

Science as a Human Endeavor

Intellectual honesty and an ethical tradition are hallmarks of the practice of science. The practice is rooted in accurate data reporting, peer review, and making findings public. This aspect of the nature of science can be taught by designing instruction that encourages students to work in groups, design investigations, formulate hypotheses, collect data, reach conclusions, and present their findings to their classmates.

The content studied in chemistry provides an opportunity to present science as the basis for engineering, ecology, computer science, health sciences and the technical trades. The diversity of chemistry content allows for looking at science as a vocation. Scientist, artist, and technician are just a few of the many careers in which a chemistry background is necessary.

Perhaps the most important aspect of this strand is that science is an integral part of society and is therefore relevant to students' lives.

Historical Perspectives

Most scientific knowledge and technological advances develop incrementally from the labors of scientists and inventors. Although science history includes accounts of serendipitous scientific discoveries, most development of scientific concepts and technological innovation occurs in response to a specific problem or conflict. Both great advances and gradual knowledge building in science and technology have profound effects on society. Students should appreciate the scientific thought and effort of the individuals who contributed to these advances.

A historical view from the philosophical perspective of Democritus (who produced no experimental evidence) to the genius of Dalton's inferences from his observation of gases, make chemistry come alive. In other examples, the history of Aristotle's philosophy of matter, and of Dalton's and Bohr's models of atomic theory, emphasize the value of a scientific model in enabling researchers to explore an unseen entity by starting with certain assumptions posited by the model.

Nature of Scientific Knowledge

Much of what is understood about the nature of science must be addressed explicitly.

- All scientific knowledge is tentative, although many ideas have stood the test of time and are reliable for our use.
- Theories "explain" phenomena that we observe. They are never proved; rather, they represent the most logical explanation based on currently available evidence. Theories become stronger as more supporting evidence is gathered. They provide a context for further research and give us a basis for prediction. For example, atomic theory is an explanation for the behavior of matter based on the existence of tiny particles. Kinetic molecular theory explains, among other things, the expansion and contraction of gases.
- Laws are fundamentally different from theories. They are universal generalizations based on observations we have made of the natural world, such as the nature of gravity, the relationship of forces and motion, and the nature of planetary movement.
- Scientists, in their quest for the best explanations of natural phenomena, employ rigorous methods. Scientific explanations must adhere to the rules of evidence, make predictions, be logical, and be consistent with observations and conclusions. "Explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific." (National Science Education Standards, 1996, p. 201)

Science as Inquiry

Inquiry should be the central theme in chemistry. It is an integral part of the learning experience and may be used in both traditional class problems and laboratory work. Because of the unique safety issues that arise in the chemistry lab, students must be given well-supervised experience in basic laboratory techniques, including safe use of materials and equipment. However, the essence of the inquiry process is to ask questions that stimulate students to think critically and to formulate their own questions. Observing, classifying, using numbers, plotting graphs, measuring, inferring, predicting, formulating

models, interpreting data, hypothesizing, and experimenting help students build knowledge and communicate what they have learned.

Inquiry applies creative thinking to new and unfamiliar situations. Students should learn to design solutions to problems that interest them. This may be accomplished in a variety of ways, but situations that present a discrepant event or ones that challenge students' intuition have been successful. Classical experiments confirming well-accepted scientific principles may be necessary to reinforce constructed understandings and to teach safe and proper use of laboratory techniques and instruments, but they should not be the whole laboratory experience. Instead, laboratory experience should be a foundation for exploring new questions. Experiments such as measurement of physical properties, decomposition of compounds, and observation of the behavior of gases should be preliminary to open-ended investigations in which students are charged with posing questions, designing experiments, recording and displaying data, and communicating. For example, after measuring physical properties, students might investigate the relationship between the density of certain liquids and their boiling points. Although original research by students traditionally has been relegated to a yearly science fair project, ongoing student involvement in this process contributes to their understanding of scientific enterprise and to their problem-solving abilities.

A solid conceptual base of scientific principles, as well as knowledge of science safety, is necessary for inquiry. Students should be given a supportive learning environment based on how scientists and engineers work. Adherence to all science safety criteria and guidelines for classroom, field, and laboratory experiences is imperative. Contact the Science Section at DPI for information and professional development opportunities regarding North Carolina specific Science Safety laws, codes, and standards. The Science Section is spearheading a statewide initiative entitled *NC-The Total Science Safety System*.

Science and Technology

It is impossible to learn science without developing some appreciation of technology. Therefore, this strand has a dual purpose: (a) developing students' knowledge and skills in technological design, and (b) enhancing their understanding of science and technology.

The methods of scientific inquiry and technological design share many common elements - objectivity, clear definition of the problem, identification of goals, careful collection of observations and data, data analysis, replication of results, and peer review. Technological design differs from inquiry in that it must operate within the limitations of materials, scientific laws, economics, and the demands of society. Together, science and technology present many solutions to problems of survival and enhance the quality of life.

The relationship between science and technology is easily seen in the discipline of chemistry. Technological design plays an important role in building chemistry knowledge. For example, electron microscopes, super-colliders, personal computers, and spectroscopes have changed our lives, increased our knowledge of chemistry, and improved our understanding of the universe. As students explore chemistry from a historical perspective, they can easily investigate the technology that contributed to knowledge in specialized areas. A relevant assignment might ask students to identify the technology used by researchers in exploring the atom and the relationships of the technology to the sophistication of the knowledge gained. Another assignment might be for students to compare the relative simplicity of Rutherford's gold foil apparatus to the space-age technology of modern super-colliders. Interviews with scientists and technicians in all areas of chemistry could provide a rich listing of the newest research instruments and the kinds of questions they seek to answer.

Science in Personal and Social Perspectives

This strand is designed to help students formulate basic understandings and implied actions for many current issues facing our society. Many examples of chemistry affecting personal and social issues can be found to help students understand the importance and applications of chemical knowledge.

Environmental Quality

Studies indicate that the general public associates "chemicals" with materials that may harm humans and/or the environment. For that reason, it is particularly important to lead students to approach such issues scientifically. There are, obviously, both negative and positive impacts from man-made chemicals, and students can gain much from conducting cost/benefit analyses of selected uses.

Such tasks emphasize the use of evidence in decision-making, a skill that transfers to every aspect of students' lives.

There are many available resources that promote one point of view or another about the use of chemicals. Having students analyze such materials for accuracy, possible bias, and misleading statements equips them to make decisions as consumers and voters. Scientists from local industries or colleges and universities can provide excellent help in evaluating such publications and, at the same time, provide information about careers in chemistry.

Science and Technology in Local, National, and Global Challenges -

This aspect of the science in personal and social perspectives strand encourages examination of the involvement of human decisions in the application of scientific and technological knowledge. "Understanding basic concepts and principles of science and technology should precede active debate about the economics, policies, politics, and ethics of various science and technology-related challenges. However, understanding science alone will not resolve local, national, or global challenges." "Students should understand the appropriateness and value of basic questions 'What can happen?' - 'What are the Odds?'- and, 'How do scientists and engineers know what will happen?'" (NSES, p. 199). The NSES emphasizes that students should understand the causes and extent of science-related challenges. They should become familiar with the advances and improvements that proper application of scientific principles and products has brought to environmental enhancement, wise energy use, reduced vehicle emissions, and improved human health.

CHEMISTRY - Grades 9-12

The Chemistry course encourages students to continue their investigations of the structure of matter along with chemical reactions and the conservation of matter and energy in those reactions. Inquiry is applied to the study of the composition, structure, properties and transformation of substances. The course focuses on basic chemical concepts and incorporates investigations to build understanding of these concepts. The unifying concepts and program strands provide a context for teaching content and process skill goals. All goals should focus on the unifying concepts:

- Systems, Order and Organization
- Evidence, Models, and Explanation
- Constancy, Change, and Measurement
- Evolution and Equilibrium
- Form and Function

Strands: The strands are: Nature of Science, Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives. They provide the context for teaching of the content goals and objectives.

COMPETENCY GOAL 1: The learner will develop abilities necessary to do and understand scientific inquiry.

Objectives

1.01 Design, conduct and analyze investigations to answer questions related to chemistry.
- Identify questions and suggest hypotheses.
- Identify variables.
- Use a control when appropriate.
- Select and use appropriate measurement tools.
- Collect and organize data in tables, charts and graphs.
- Analyze and interpret data.
- Explain observations.
- Make inferences and predictions.
- Explain the relationship between evidence and explanation.
- Identify how scientists share findings.

1.02 Analyze reports of scientific investigations from an informed scientifically-literate viewpoint including considerations of:
- Appropriate sample.
- Adequacy of experimental controls.
- Replication of findings.
- Alternative interpretations of the data

1.03 Analyze experimental designs with regard to safety and use safe procedures in laboratory investigations:
- Identify and avoid potential safety hazards given a scenario.
- Differentiate between safe and unsafe procedures.
- Use information from the MSDS (Material Safety Data Sheets) to assess chemical hazards.

COMPETENCY GOAL 2: The learner will build an understanding of the structure and properties of matter.

Objectives

2.01 Analyze the historical development of the current atomic theory.
- Early contributions: Democritus and Dalton.
- The discovery of the electron: Thomson and Millikan.
- The discovery of the nucleus, proton and neutron: Rutherford and Chadwick.
- The Bohr model.
- The quantum mechanical model.

2.02 Examine the nature of atomic structure.
- Subatomic particles: protons, neutrons, and electrons.
- Mass number.
- Atomic number.
- Isotopes.

2.03 Apply the language and symbols of chemistry.
- Name compounds using the IUPAC conventions.
- Write formulas of simple compounds from their names.

2.04 Identify substances using their physical properties:
- Melting points.
- Boiling points.
- Density.
- Solubility.

2.05 Analyze the basic assumptions of kinetic molecular theory and its applications:
- Ideal Gas Equation.
- Combined Gas Law.
- Dalton’s Law of Partial Pressures.

2.06 Assess bonding in metals and ionic compounds as related to chemical and physical properties.

2.07 Assess covalent bonding in molecular compounds as related to molecular geometry and chemical and physical properties.

- Molecular.
- Macromolecular.
- Hydrogen bonding and other intermolecular forces (dipole/dipole interaction, dispersion).
- VSEPR theory.

2.08 Assess the dynamics of physical equilibria.
- Interpret phase diagrams.
- Factors that affect phase changes.

COMPETENCY GOAL 3: The learner will build an understanding of regularities in chemistry.

Objectives

3.01 Analyze periodic trends in chemical properties and use the periodic table to predict properties of elements.
- Groups (families).
- Periods.
- Representative elements (main group) and transition elements.
- Electron configuration and energy levels.
- Ionization energy.
- Atomic and ionic radii.
- Electronegativity.

3.02 Apply the mole concept, Avogadro's number and conversion factors to chemical calculations.
- Particles to moles.
- Mass to moles.
- Volume of a gas to moles.
- Molarity of solutions.
- Empirical and molecular formula.
- Percent composition.

3.03 Calculate quantitative relationships in chemical reactions (stoichiometry).
- Moles of each species in a reaction.
- Mass of each species in a reaction.
- Volumes of gaseous species in a reaction.

COMPETENCY GOAL 4: The learner will build an understanding of energy changes in chemistry.

Objectives

4.01 Analyze the Bohr model in terms of electron energies in the hydrogen atom.
- The spectrum of electromagnetic energy.
- Emission and absorption of electromagnetic energy as electrons change energy levels.

4.02 Analyze the law of conservation of energy, energy transformation, and various forms of energy involved in chemical and physical processes.
- Differentiate between heat and temperature.
- Analyze heating and cooling curves.
- Calorimetry, heat of fusion and heat of vaporization calculations.
- Endothermic and exothermic processes including interpretation of potential energy.
- Diagrams (energy vs reaction pathway), enthalpy and activation energy.

4.03 Analyze the relationship between entropy and disorder in the universe.

4.04 Analyze nuclear energy.
- Radioactivity: characteristics of alpha, beta and gamma radiation.
- Decay equations for alpha and beta emission.
- Half-life.
- Fission and fusion.

COMPETENCY GOAL 5: The learner will develop an understanding of chemical reactions.

Objectives

5.01 Evaluate various types of chemical reactions.
- Analyze reactions by types: single replacement, double replacement (including acid-base neutralization), decomposition, synthesis, and combustion including simple hydrocarbons.
- Predict products.

5.02 Evaluate the Law of Conservation of Matter
- Write and balance formulas and equations.
- Write net ionic equations.

5.03 Identify and predict the indicators of chemical change.
- Formation of a precipitate.
- Evolution of a gas.
- Color changes.
- Absorption or release of heat.

5.04 Identify the physical and chemical behaviors of acids and bases.
- General properties of acids and bases.
- Concentration and dilution of acids and bases.
- Ionization and the degree of dissociation (strengths) of acids and bases.
- Indicators.
- Acid-base titration.
- pH and pOH.

5.05 Analyze oxidation/reduction reactions with regard to the transfer of electrons.

- Assign oxidation numbers to elements in REDOX reactions
- Identify the elements oxidized and reduced.
- Write simple half reactions.
- Assess the practical applications of oxidation and reduction reactions.

5.06 Assess the factors that affect the rates of chemical reactions.

- The nature of the reactants.
- Temperature.
- Concentration.
- Surface area.
- Catalyst.